99.9
644n
1.7

VARIATION IN CHAR DENSITY ON LABORATORY FUELS

Ralph A. Wilson and Merlin L. Brown[1]

ABSTRACT

*Residual char from 76 test burns of wood dowels showed
unexpectedly wide variation in density. Variation could
not be correlated with initial fuel density, burn time,
nor incident windspeed.*

KEYWORDS: char, char density, combustion products

While supporting a study of the aerodynamics of burning firebrands, the authors
made 76 measurements of char density from free-burning wood (pine *Pinus ponderosa* and
birch *Betula* spp.) fuels. We observed an unexpectedly wide variation in the density
measurements of the residual char and have found no previous report of the effects.

The fuel samples were pine or birch dowels of various diameters (3/8, 1/2, 1 inch
diameter by 5 inches long). Initial fuel characteristics were carefully measured.
Ignition and burning conditions were held constant (except for windspeed which was set
at values between 0 and 15 miles per hour).

The dowels were ignited in an oxy/gas flame with cylindrical symmetry and were
burned with axis vertical in a horizontal wind. After a measured burn time the fire
was quenched in dry nitrogen (cooled in dry ice). After quenching, densities were
determined by direct weight and volume measurements for (1) the total residual material;
(2) the unpyrolyzed core; and (3) the residual char. The "char" included all pyrolyzed
(mechanically weak) material that would crumble away from the solid core with very
little force. In all cases, the char/core surface was well defined: the transition
thickness was <<1 mm. Volumes were determined by an Archimedes technique modified to
account for water absorbed by the char during immersion. This technique was verified
by dimensional measurements when the residual char was sufficiently contiguous and
intact. The errors of measurement are at least one order of magnitude smaller than the
range of observed char density.

The resulting data for "char" are presented in tables 1 and 2; the density distributions are plotted in figure 1. We could find no significant correlation of char density with initial wood density, burn time, or windspeed. Our first speculation was that this wide range of densities is due to variation in the amount of heavy tars and waxes that are collected in the char as they diffuse away from the combustion zone. Several additional char samples were prepared and analyzed by means of the Reaction

Table 1.--*Density measurements of birch char*

Burn No.	:	Initial diameter Cm	:	Initial density G/Cm^3	:	Wind-speed Mi/h	:	Burn time Min	:	Char density G/Cm^3
22		2.52		0.638		0		1.0		0.23
23		2.55		.618		0		2.0		.22
24		2.41		.634		0		3.0		.19
25		2.39		.629		0		4.0		.26
26		2.43		.605		0		5.0		.28
27		2.48		.572		0		6.0		.18
55		2.50		.557		5		.5		.26
56		2.50		.554		5		.5		.18
9		2.49		.598		5		1.0		.23
57		2.51		.556		5		1.5		.28
58		2.50		.553		5		1.5		.20
10		2.50		.601		5		2.0		.31
59		2.50		.572		5		2.5		.21
11		2.49		.602		5		3.0		.23
60		2.41		.583		5		3.5		.36
72		2.46		.611		5		3.5		.20
12		2.49		.595		5		4.0		.24
73		2.45		.597		5		4.0		.27
61		2.45		.568		5		4.5		.26
74		2.45		.600		5		4.5		.21
13		2.49		.581		5		5.0		.15
75		2.41		.619		5		5.0		.30
62		2.42		.587		5		5.5		.30
76		2.50		.606		5		5.5		.25
14		2.51		.619		15		1.0		.19
15		2.50		.615		15		2.0		.31
16		2.48		.577		15		3.0		.21
17		2.47		.588		15		3.0		.16
35		.99		.682		2		1.0		.12
36		.99		.681		2		1.0		.22
37		1.22		.665		2		1.0		.17
38		1.21		.709		2		1.0		.22
39		2.49		.525		2		1.0		.24
40		2.48		.527		2		1.0		.22
50		2.41		.665		2		2.0		.28
51		2.39		.554		2		2.0		.23
52		2.49		.708		2		2.0		.25
53		2.55		.729		2		2.0		.24
54		2.40		.566		2		2.0		.20

Coulometer [2] for volative combustion products. The result of this test was negative; the char held no tars or combustion products that vaporize below 500° C.

The implication is that a probabilistic density distribution of residual carbon remains as char after a process of incomplete combustion. If so, the effect should be significant to fire modelers, particularly those concerned with energy balance in combustion of solid fuels.

Table 2.--*Density measurements of pine char*

Burn No.	: :	Initial diameter Cm	: :	Initial density G/Cm^3	: :	Wind- speed Mi/h	: :	Burn time Min	: :	Char density G/Cm^3
28		2.50		0.481		0		1.0		0.20
29		2.51		.469		0		2.0		.12
30		2.48		.432		0		3.0		.17
31		2.49		.438		0		4.0		.15
32		2.47		.475		0		5.0		.22
33		2.50		.473		0		6.0		.14
34		2.49		.480		0		15.0		.34
63		2.46		.470		5		.5		.17
1		2.51		.465		5		1.0		.15
64		2.42		.488		5		1.5		.21
2		2.54		.464		5		2.0		.17
65		2.40		.486		5		2.5		.19
3		2.50		.474		5		3.0		.29
4		2.49		.465		5		3.0		.16
66		2.45		.471		5		3.5		.31
5		2.53		.462		5		4.0		.17
67		2.45		.463		5		4.5		.14
68		2.41		.491		5		5.0		.17
69		2.41		.464		5		5.5		.11
6		2.41		.487		5		6.0		.29
70		2.45		.449		5		6.5		.10
7		2.42		.486		5		7.0		.22
71		2.41		.460		5		7.5		.19
8		2.50		.457		5		8.0		.36
18		2.45		.482		15		1.0		.18
19		2.49		.477		15		2.0		.26
20		2.45		.488		15		3.0		.15
21		2.51		.462		15		3.0		.07
41		1.30		.483		2		1.0		.13
42		1.29		.527		2		1.0		.14
43		2.44		.451		2		1.0		.10
44		2.48		.427		2		1.0		.14
45		2.48		.427		2		2.0		.15
46		2.49		.439		2		2.0		.16
47		2.58		.477		2		2.0		.20
48		2.53		.507		2		2.0		.22
49		2.50		.519		2		2.0		.17

[2]R. A. Susott, F. Shafizadeh, and T. Aanerud. A quantitative thermal analysis method for combustible gas detection. Manuscript in preparation, Northern Forest Fire Laboratory, Missoula, Montana.
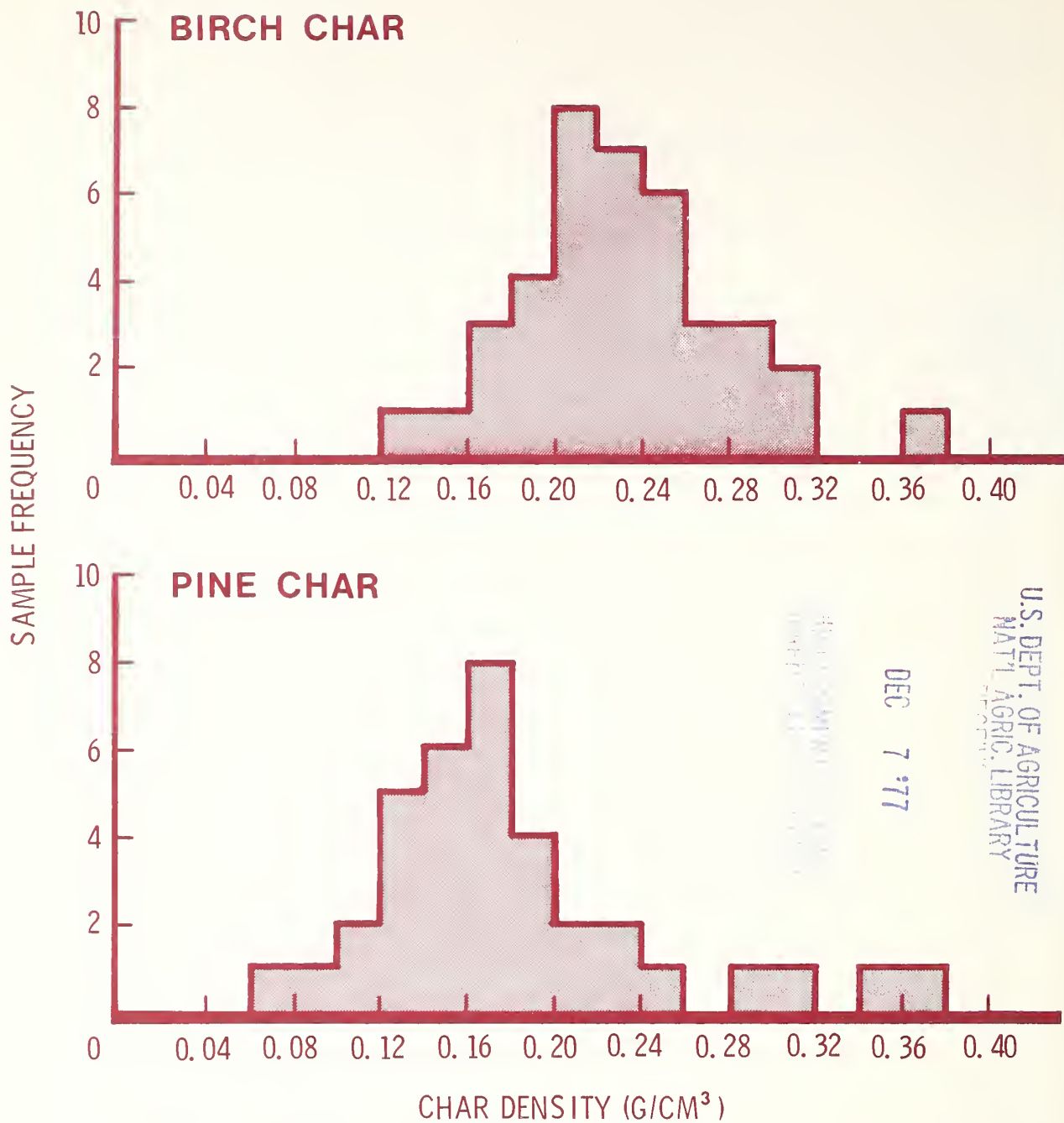
Figure 1.--Density distributions of char formed on birch and pine dowels.